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Herbicide and Fire Effects on Leafy Spurge Density and Seed Germination

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Where dense stands of leafy spurge (*Euphorbia esula*) have become established in Northern Great Plains rangelands, native plant communities have been severely impacted. A spring or fall prescribed burn, a single application of picloram plus 2,4-D, and a combination of fire and herbicides were evaluated as techniques to reduce stands of leafy spurge. A spring burn with or without a fall herbicide application was the most effective treatment for reducing leafy spurge seed germination. Herbicides with or without burning were most effective in reducing leafy spurge stand density. Picloram plus 2,4-D applied in the fall followed by spring burning provided the best control of leafy spurge density and seed germination on the Little Missouri National Grassland.

Keywords: leafy spurge, *Euphorbia esula*, mixed grass prairie, North Dakota, picloram, 2,4-D

Leafy spurge (*Euphorbia esula*) is a deep-rooted, Eurasian perennial forb that thrives in a wide variety of habitats throughout the northern United States and southern Canada. In the Northern Great Plains, leafy spurge occupies over 1.1 million ha (Dunn 1979). Leistritz et al. (1992) estimated the annual regional net economic impact from leafy spurge infestations to be about $75 million when impacts on ranch incomes and regional economies are considered.

Leafy spurge spreads rapidly from seed and by an extensive underground root system (Watson 1985). A single leafy spurge seed stalk can produce up to 150 seeds per year. At maturity, seeds are expelled up to 4.6 m when the ripe fruit dehisces (Bakke 1936). Most seeds germinate the following spring when air temperatures reach approximately 28°C (Messersmith 1983). However, seeds may remain viable in the soil as long as 8 years (Selleck et al. 1962). Thus, for long-term control of leafy spurge, treatments must be repeated annually for at least 8 years to prevent reinfestation from seed and regrowth from crown buds and adventitious buds on the deep root system (Watson 1985).

The depth and longevity of the leafy spurge root system, along with its ability to reproduce vegetatively, make this plant very persistent (Coupland et al. 1955). Leafy spurge's long roots grow horizontally and invade new areas; they also produce buds and establish new growth centers (Raju 1985). Further, the production of these buds is enhanced by injury. Root systems have lived up to 6 years (Selleck et al. 1962), and they have the capability of producing new shoots from various depths and from root fragments (Messersmith 1983).

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Leafy spurge can generally be controlled with herbicides (Chow 1984, Hickman et al. 1990, Lym and Messersmith 1985b); however, treatment success can vary from year to year. The cost effectiveness of chemical treatments also varies with time, area treated, and the herbicide used (Lym and Messersmith 1983, 1990). Picloram provides the best long-term control of leafy spurge on grasslands, but the dosage required is often not cost- effective (Bakke 1936, Lym and Whitson 1991). Applying picloram annually at 0.28 kg ha^{-1} or picloram at 0.28 kg ha^{-1} plus 2,4-D at 1.1 kg ha^{-1} are the most effective methods for controlling leafy spurge (Lym and Messersmith 1983). Chemical treatments have to be repeated periodically due to reinfestation from seed reserves in the soil and from crown and root buds. Therefore, a low-cost treatment or series of treatments that control top growth and inhibit seed germination would reduce the spread of this noxious weed.

Limited research has been conducted to determine the effects of herbicides on germination of leafy spurge seed. Bowes and Thomas (1978) reported that soaking leafy spurge seeds in picloram did not inhibit germination. The influence of herbicides combined with burning treatments on leafy spurge density and seed germination has not been documented.

Although little research has been conducted on the effects of prescribed burning on leafy spurge, fall burning in western North Dakota reduced its frequency (Dix 1960). Plant seeds are generally tolerant of heat (Daubenmire 1968), but given higher temperatures associated with heavy fuel loads and longer burn times, some seed mortality can be expected (Wright and Bailey 1982). Fire can also be used as a follow-up treatment to herbicides under the premise that sprouting induced by burning will further deplete carbohydrate reserves of already damaged plants. Thus, the objective of this study was to evaluate the effectiveness of herbicides and fire, applied alone or in combination, in reducing leafy spurge density and seed germination.

Study Area

The study was conducted on the Little Missouri National Grassland in southwestern North Dakota, which is administered by the USDA Forest Service. The area is approximately 30 km northeast of the town of Beach. Precipitation at Beach averages 38 cm annually, 77% of which occurs between April and September (National Oceanic and Atmospheric Administration 1990). The dramatic expansion of leafy spurge on the Little Missouri National Grassland is a serious concern (McIntyre 1979).

Two study sites were established: an upland site in the East Twin Butte Allotment, and, approximately 8 km northeast, a floodplain site in the Wannagan Creek Allotment. Plant species present on the East Twin Butte study site in addition to leafy spurge were big bluestem (*Andropogon gerardii*[3]), little bluestem (*A. scoparium*), western wheatgrass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), and buffalo grass (*Buchloe dactyloides*). Besides leafy spurge, the Wannagan Creek study site had remnants of big sagebrush (*Artemisia tridentata*) and silver sagebrush (*A. cana*), western wheatgrass, needle-and-thread (*Stipa comata*), and green needlegrass (*S. viridula*).

Methods

Twenty-one 15.2-m^2 plots were delineated on each study site in May 1985. The design was a randomized complete block, where plots were arranged in 3 rows of 7 plots each in dense, relatively uniform stands of leafy spurge. Treatments were randomly assigned within rows. Each plot was separated by a 3 m border on all sides, and each study site was fenced to prevent livestock grazing during the study.

Treatments tested to determine which combination of burning and herbicide best controlled leafy spurge included:

1) herbicide only applied in the spring
2) herbicide only applied in the fall
3) herbicide applied in the spring followed by a fall burn
4) herbicide applied in the fall followed by a spring burn
5) spring burn only
6) fall burn only
7) untreated control.

The herbicide treatment was a mixture of 0.28 kg of picloram and 1.1 kg of 2,4-D, applied in 470 liters of water per hectare. The herbicide mix was applied by a certified applicator using a low pressure (2.9 to 5.8 kPa) pickup-mounted sprayer. Spring and fall herbicide treatments were applied 19 June and 15 September 1985, respectively. Backing fires (where the fire moves against the wind) were used on the burn treatments on 19 September 1985 and 4 May 1986. A combination of mowing and commercial fire retardant was used to contain the fires within designated treatment boundaries.

Leafy Spurge Seed Germination

Germination rates of leafy spurge seed in the upper 10 cm of soil and in the soil surface mulch were compared among treatments. Nine systematically spaced soil samples were collected from each plot with a 30-cm^2 bulk-density sampler to a depth of 10 cm. Samples

[3]*Great Plains Flora Association (1986) is the authority for common and scientific names.*

were placed in individual plastic bags for transport and storage. Soil samples were kept moist and in cool storage (< 30°C) until the seeds were separated from the soil and surface mulch. Within 5 days of collection, 200 leafy spurge seeds were randomly selected from the 9 composited samples from each plot. The seeds were placed in a germinator programmed to alternate between 20 and 30°C; each temperature period lasted 8 hours. The germination trial was conducted for 30 days. The best leafy spurge germination can be expected with alternating temperatures in the range of 20 to 30°C for at least 14 days (Messersmith et al. 1985). Seeds were examined daily for appearance of the hypocotyl — an indication of germination.

Leafy Spurge Density

Density of leafy spurge stems in each of the plots was evaluated in early July 1986. The number of leafy spurge stems was counted in 20 0.1-m^2 quadrats randomly positioned in each plot. Stem counts were summarized and converted to number/m^2.

Statistical Analysis

Homogeneity of variances of seed viability and plant density were tested using Bartlett's test (Steel and Torrie 1960). Square root transformation was used to control heterogeneous variances. Differences among treatments in number of seeds that germinated and stem densities were evaluated by two-way analyses of variance (Steel and Torrie 1960). Mean differences were considered significant at the 5% probability level according to Tukey's *w*-procedure (Steel and Torrie 1960). Transformed data were converted to actual percent germination for presentation.

Results and Discussion

Leafy Spurge Seed Germination

Germination of leafy spurge seeds collected from both upland and floodplain sites ranged from < 1% to nearly 5%. Other researchers have reported germination rates between 51% and 84% (Messersmith et al. 1985), although Selleck et al. (1962) reported germination rates of < 1% to 44%. The variability in germination could be due to genetic differences in seed dormancy or viability, environmentally induced dormancy, or an after-ripening phenomenon (Messersmith et al. 1985). Genetic differences within sites in our study are unlikely, since it is likely the plants all have a similar genetic makeup; however, both dormancy and after-ripening may have contributed to low germination rates.

In spite of the low germination rates observed in our study, rates varied among seasons and treatments (table 1). All treatments, except the spring herbicide application, significantly depressed leafy spurge seed germination relative to the untreated plots on both upland and floodplain sites. Fall herbicide + spring burn or a spring burn alone were the most effective treatments in reducing leafy spurge seed germination; both of these treatments reduced leafy spurge seed germination by over 95% compared to untreated plots. Spring herbicide + fall burn was more effective in reducing leafy spurge seed germination than either spring or fall herbicide application without fire. Fall herbicide provided a slight but significant reduction in germination compared to no treatment, as did fall burning alone.

All burn treatments substantially reduced the germination of leafy spurge seed compared with no treatment; spring burns were slightly more effective than fall burns. However, natural loss in seed viability may have been greater on spring burn sites than on fall burn sites due to winter mortality. Viability of leafy spurge seed generally diminishes slowly over time (Bowes and Thomas 1978). Our study suggested that a single spring burn is an effective method to reduce leafy spurge seed germination.

Herbicides alone did little to decrease germination of leafy spurge seed (table 1). Similar findings were reported by Bowes and Thomas (1978). The general effectiveness of fall herbicide/spring burn treatment on leafy spurge seeds was attributed to the lethal effects of fire. Prescribed burning has been used in other areas to reduce germination of downy brome (*Bromus tectorum*) and medusahead (*Taeniatherum asperum*) seeds (Young et al. 1972). More research on lethal temperatures is necessary to fully understand the mechanisms involved in reducing seed germination rates observed in our study.

Leafy Spurge Density

Leafy spurge density was not influenced by site (upland or floodplain), but was influenced by treatment. All herbicide treatments, with or without a followup burn, reduced the density of leafy spurge compared to untreated plots or burned-only treatments (table 2). Previous field studies also reported excellent control of leafy spurge with picloram plus 2,4-D (Lym and Messersmith 1985a, 1985b).

Burning did not reduce leafy spurge density; to the contrary, fire top-killed the leafy spurge plants and stimulated vigorous sprouting. Picloram plus 2,4-D with or without burning controlled leafy spurge better than burning alone. Although our study did not evaluate long-term effectiveness, Lym and Messersmith (1985a) noted that picloram plus 2,4-D provides excellent control for up to 15 months after treatment, al-

Table 1.—Germination (%) of leafy spurge seed collected on two Little Missouri National Grassland study sites following herbicide and burn treatments.[1]

Treatment	Study site: Floodplain			Study site: Upland		
	Germination (% ± standard error)					
Fall herbicide[2] + spring burn	0.17	±	0.08 [a]	0.80	±	0.12 [ab]
Spring herbicide + fall burn	0.90	±	0.20 [ab]	1.33	±	0.32 [bc]
Spring burn	0.23	±	0.08 [a]	0.73	±	0.11 [ab]
Fall burn	1.07	±	0.24 [bc]	2.47	±	0.32 [de]
Fall herbicide	1.57	±	0.37 [bc]	1.70	±	0.32 [cd]
Spring herbicide	3.40	±	0.55 [de]	3.33	±	0.42 [ef]
Untreated	4.93	±	0.67 [e]	3.83	±	0.35 [f]

[1]*Values followed by different letters are significantly different ($P < 0.05$).*
[2]*All herbicide treatments were picloram at 0.28 kg ha^{-1} plus 2, 4-D at 1.1 kg ha^{-1}.*

Table 2.-Leafy spurge stem density on Little Missouri National Grassland study sites following herbicide and burn treatments.[1]

Treatment	Density		
	number m^{-2} ± standard error		
Spring herbicide[2] + fall burn	14	±	8 [a]
Fall herbicide + spring burn	67	±	22 [a]
Spring herbicide	33	±	14 [a]
Fall herbicide	41	±	11 [a]
Fall burn	228	±	107 [ab]
Spring burn	364	±	41 [b]
Untreated	239	±	28 [b]

[1]*Values followed by different letters are significantly different ($P < 0.05$).*
[2]*All herbicide treatments were picloram at 0.28 kg ha^{-1} plus 2, 4-D at 1.1 kg ha^{-1}.*

though annual application of the herbicide is necessary for long-term control.

These preliminary data indicate that a spring burn with or without a fall herbicide application was the most effective treatment for reducing leafy spurge seed germination. Herbicides with or without burning were most effective in reducing leafy spurge stem density. Therefore, the best all-around treatment for reducing both germination and stem density would be a fall application of picloram plus 2,4-D followed by spring burning. Additional research is needed to verify these initial results.

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